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PRECISION VERNIER POTENTIOMETER

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TYPE 9144

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Fig.

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IMPORTANT

The accuracy of voltage and current measurements depends (a) on the known accuracy of the standard cell voltage relative to the national standards, (b) on the accuracy of agreement between the potentiometer standard cell circuit and the measuring circuit and (c) on the linearity of the measuring circuit.

In the construction of this potentiometer considerably more attention has been given to the linearity of the measuring circuit than to the relationship between the measuring circuit and the standard cell circuit. In order to utilise to the full the high linearity of the measuring circuit, it is essential to consider this linearity separately and to make an independent determination of the error in agreement between the measuring and standard cell circuits. Using the procedure described in paragraph 9.10 the error in agreement can be quickly obtained.

When the linearity of the measuring circuit is thus determined separately it is possible to take full advantage of this linearity by standardising directly against the measuring circuit and thus eliminating the error due to (b) above. Similarly, comparison of external standard cells and the comparison of nominally equal resistors can be carried out directly against the measuring circuit without correction for (b).

oOo

SEALS

The case of this instrument is sealed in two places. The outer seal is on the screw in the left back corner of the top panel. It is necessary to break this seal to obtain access to the switches for cleaning purposes at approximately yearly intervals.

The inner seal is at the left hand end of the binding post strip. It is necessary to break this seal to remove the instrument from the box.

REMOVAL OF THE INNER SEAL CANCELS THE GUARANTEE ON THE INSTRUMENT

PRECISION VERNIER POTENTIOMETER

TYPE 9144

1. GENERAL

The Type 9144 potentiometer was designed by Dr. T.M. Dauphinee of National Research Council, Ottawa, following a study of the present state of the art of potentiometer design and manufacture. The resulting circuit and method of construction embodies the desirable features of the classical potentiometer circuits with the addition of several new features.

2. CONSTRUCTION

The switches and all electrical components of the potentiometer are mounted on an aluminum panel which is enclosed in a copper box. A distributed heater winding covers the outside of the copper box. Between the copper box and the outer wooden case is a layer of polyethylene foam insulation and an electrostatic shield.

The enamelled top panel is attached to the instrument sub-panel by five 18-32 countersunk screws (two at each end and one near the thermometer), and the top panel is held to the wooden box by four 8-32 countersunk screws. The outer wooden case and lid are of ruggedized Formica construction.

3. DIALS, CONTROLS AND TERMINALS

3.1) Measuring Dials

The potentiometer has four measuring dials giving voltage increments on the x1 range as follows:-

Dial I	20 steps of 0.1 volt	2.000 000
Dial II	100 steps of 0.001 volt	0.100 000
Dial III	100 steps of 0.000 01 volt	0.001 000
Dial IV	10 steps of 0.000 001 volt	0.000 010
	Total	2.101 010

Dial III has a single negative step of 0.000 01 volt. Both Dial II and Dial III have an extra heavy detent between the 100 and 0 positions to indicate to the operator that a full dial increment is taking place as the dial is rotated through one step.

3.2) Range Switch

The range switch has three positions marked x1 volts, x0.1 volts and x10 ohms. The first two switch positions give the conventional potentiometer ranges in which the reading of the four measuring dials are either read directly as indicated by the panel engraving or reduced by a factor of 10. The third range switch position changes the effective resistance between the EMF terminals so that when the potentiometer is being used as a variable four terminal resistor, the unit increments on dial I are 1 ohm. (See Para. 4.5 for details of resistance ranges).

3.3) Check Switch

The check switch has six positions, five of which are used in the linearity checking procedure described in Para. 9. The sixth position marked "Read" is the position used for normal operation of the potentiometer.

3.4) Current Control

The potentiometer current is controlled by a five dial rheostat marked x10, x1, x0.1, Fine 1 and Fine 2. The discrimination of this rheostat is such that the potentiometer current can be controlled to within 1 part per million.

3.5) Standard Cell Voltage Dial

The standard cell voltage range is from 1.017 500 to 1.020 100 volt. This variation is covered in 25 steps of 100 microvolts plus 100 microvolts on the concentric continuously variable dial. The continuously variable dial carries two sets of engraving. The black divisions marked 0-100 are used with the standard cell dial. The red engraving -50 to +50 is used with the reference potentials.

3.6) Reference Potentials and Standard Cell Selector

As can be seen in the schematic diagram a reference network is provided at the right hand end of the potentiometer circuit. Tappings on this circuit at 0.1, 0.2, 0.5 and 1 volt are connected to the standard cell and reference potential switch. The resistance of each of the sections of the reference network is adjusted to agree with corresponding sections of the main potentiometer when the standard cell fine control is set to the center or zero position as indicated by the red engraving. Each of the indicated voltages is connected to the SCX terminals through the REF galvanometer sensitivity keys when the switch is turned to the corresponding position.

3.7) Terminals and Links

Access to the terminals is obtained by lifting vertically the strip panel at the back of the instrument. The strip panel serves to protect the terminals against temperature differences caused by air currents and should be removed only for the purpose of making and removing connections.
The terminals have long copper stems. Incoming insulated leads should be taken around the stem three or four times before making electrical

connection under the terminal head screw. This serves to bring the temperature of the wire to the same temperature as the potentiometer internal wiring before making electrical connection and thus reduces thermal emfs.

G_1, G_1, G_D, G_D — for connection of the measuring galvanometer and galvanometer damping resistor.

EMF — Measuring circuit terminals (also serve as potential terminals when used as a four terminal resistor).

CK — Check terminals; (normally linked) used in the linearity checking procedure described in Para. 9.

C_0 — "Current In" terminal, when used as a four terminal resistor.

G_2, G_2, G_D, G_D — for connection of a monitoring galvanometer and its associated damping resistor.

SCX — for connection of an external standard cell or for use with reference potentials.

BATT — for connection of the potentiometer 6 volt supply battery. The positive terminal is also used as the "Current Out" terminal, C_1, when using the potentiometer as a four terminal resistor.

GND — Ground terminal connected to the top panel and electrostatic shield.

Two copper links are provided. These are normally held by the 'CK' terminals and are intended for use in this position or between the 'SCX' terminals. A link should not be left permanently connected across the 'SCX' terminals because there is a risk that if the standard cell selector switch should be inadvertently turned to SC1 or SC2 at a time when the potentiometer battery is disconnected, a 50 ohm load would be applied to the standard cell through the REF sensitivity keys and the galvanometer.

3.8) Galvanometer Sensitivity Keys

Two sets of five galvanometer keys are provided. The left hand set marked "Test" are in the measuring circuit and give increasing galvanometer sensitivity in the sequence 1, 2, 3, 4. The press key marked R reverses the galvanometer. Key 1 inserts a 10 megohm resistor in series with the galvanometer. Key 2 reduces this to 250K ohms and key 3 reduces it to 5K ohms. No series resistance is introduced by the 4 and R keys. The externally connected galvanometer damping resistor is connected in parallel with the galvanometer terminals at all times except when the high sensitivity keys are depressed. In the 4 and R sensitivity conditions the damping resistor is removed from the circuit. The press keys can be converted from locking to non-locking by rotation of press key #1. When the two dots are in line from front to back of the potentiometer the keys will lock down. Rotation of the #1 button to put the dots in line with the front edge of the potentiometer makes the press keys non-locking.
The right hand set of five galvanometer keys are connected in the reference circuit and are used during standardisation or in conjunction with the

reference potentials. Their function is exactly similar to that of the "Test" keys. All galvanometer keys are of double pole construction. The same galvanometer can therefore be connected simultaneously to both the "Test" and "Reference" circuits and can be connected separately to either circuit by pressing the appropriate keys.

4. ELECTRICAL CIRCUIT

4.1) General

The elements of the electrical circuit are shown in the appended schematic diagrams. Dials I and II are connected in series and Dials III and IV operate as Vernier elements on Dials I and II respectively. Series and shunt resistors are used with the potentiometer chain to obtain the required x1V, x0,1V and x10 ohms ranges. The standard cell circuit and reference voltages are connected in series with the main potentiometer. Check resistors are provided to enable the user to make a quick check on the linearity of the instrument.

4.2) Battery Circuit and Current Control

The main potentiometer between points ABC(Fig. 2a) has a resistance of 150 ohms and this is shunted in the x1 position of the range switch, by 1500 ohms. The resultant resistance between points A and C is 136.36 ohms and this value is maintained on the x0.1 range by the addition of 1350 ohms in series with 150Ω potentiometer and the reduction of the shunt from 1500 ohms to 150 ohms (Fig. 2b). The current through the combined potentiometer and shunt circuit is 20mA on both ranges. The resistance

of the series reference circuit between points C and D is 51 ohms and the residual resistance of the current control rheostat R is approximately 80 ohms. The minimum resistance presented to the battery is therefore approximately 267 ohms and for 20mA current the minimum usable battery voltage is 5.34 volts. The rheostat resistance can be increased from 80 ohms to 191 ohms giving a maximum total resistance at the battery terminals of 378 ohms which can accommodate a maximum battery voltage of 7.56. The total end to end change on the Fine 2 control is approximately 0.01 ~~0.005~~ ohm. In a circuit of total resistance 267 ohms this represents a change of about 20 parts per million and if the full rheostat resistance were in circuit the end to end change of resistance of the Fine 2 control would give a current change of approximately 12 parts per million. It is therefore easily possible to adjust the potentiometer current to within 1 ppm.

4.3) Galvanometer Circuits

The measuring galvanometer is connected in series with the "Test" sensitivity keys and through the EMF and CK terminals to Dials III and IV. The potentiometer presents a minimum resistance of 5† ohms to the galvanometer when the four measuring dials are in the zero position. This resistance increased to 150 ohms when the measuring dials are set to maximum readings.

The "REF" galvanometer is connected in series with the "SCX" terminals

† Except in instruments in which both dials III and IV are provided with a constant resistance facility. In such instruments the minimum and maximum resistances are 35 and 150 ohms respectively.

and the "REF" sensitivity keys to the reference circuit. The resistance of this circuit is 50 ohms per volt plus the internal resistance of the standard cells.

4.4) Voltage Ranges

On the x1 range the potential at the EMF terminals is as indicated by the engraving on the four measuring dials, giving a maximum of 2.101 010 volts in steps of 1 microvolt and with a negative position on Dia. III giving -10 microvolts.

On the x0.1 range the current through the measuring network is reduced by a factor of 10 and the potential at the EMF terminals is one-tenth of that indicated by the engraving on the four measuring dials. The total is then 0.210 101 0 in steps of 0.1 microvolt and the negative step on Dial 3 gives -1 microvolt.

4.5) Variable Resistance Ranges

The potentiometer can be used as a variable 4 terminal resistance on all three ranges.

Range	Max. effective resistance between EMF terminals	Smallest increment on Dial IV	Resistance between current terminals C_I, C_0
x0.1V	10.505 050Ω	5uΩ	136.36Ω
x1V	105.050 50Ω	50uΩ	136.36Ω
x10Ω	21.010 10Ω	10uΩ	245.45Ω

When the potentiometer is used as a four terminal resistor, the potential appearing at the EMF terminals is that which would be due to a current passing from C_I to C_0 through a resistor having a value indicated by the setting of the measuring dials in accordance with the table above. The

current at the C_I C_0 terminals should not exceed 100mA.

4.6) Standard Cell Circuit and Internal Cells

There are two saturated standard cells in a sealed compartment inside the temperature controlled box. The voltages of these two cells at the thermostatting temperature are given in the appendix. These figures are accurate to ±50 microvolts, but their value can be established more precisely by comparison with a certified external cell. Following transportation of the potentiometer such comparisons should not be made until the internal cells have been held at the thermostatting temperature for at least two weeks. If the power supply to the heaters is disconnected and the cells are allowed to cool, a further period of at least 48 hours should elapse before the accurately established figure is used.

The internal saturated standard cells are not intended to be used as long term standards. They are intended only for use as convenient working reference cells after their values have been established by comparison with a certified external cell. This should be done by the procedure described in Para. 7.11 which automatically takes into account any error between the S.C. dial and the measuring dials.

4.7) Trimming Resistors

In various critical parts of the potentiometer circuit small adjustable trimming resistors have been connected. These provide for adjustment over a few parts per million and if, after one or two years, the instrument is returned to the factory for calibration check and overhaul, these trimmers can be used to make minor adjustments to compensate for long term drift

without physically disturbing the resistance elements. The inevitable stabilisation drift that follows re-adjustment of a resistor is thus avoided.

THE USER IS STRONGLY ADVISED NOT TO TOUCH OR IN ANY WAY DISTURB THE RESISTANCE COILS OR THE VARIABLE TRIMMING RESISTORS.

4.8) Switches

With one exception all switch contacts in the potentiometer are of copper construction. In some cases the emphasis is on good reproducibility of contact resistance and in others the emphasis is on the reduction of thermal emfs to a minimum.

In the current control rheostat and the range switch it is important that contact resistance shall be small and stable. In dials I and II it is important to minimise thermal emfs, but the circuit arrangement is such that in these two cases the contact resistance is relatively unimportant. The most critical contact resistance is at the right hand contact of Dial I where an error less than one step of Dial IV would be caused by a change in contact resistance of 0.01Ω. Other permissible contact resistance variations in Dial I and II may be as large as 0.5Ω, 1 ohm and 10 ohms and are therefore even less critical. The procedure for cleaning the switches is described in Paragraph 11.

4.9) Electrostatic Shield

The aluminum top panel and an aluminum shield on the inside of the wooden box are connected to the "GND" terminal. These constitute an effective electrostatic shield on the potentiometer circuit components.

5. BATTERY

A six volt battery is required to supply the potentiometer. This should be connected to the battery terminals and should remain connected except when removed for recharging. A battery of the charge-retaining type with a capacity of 100AH is recommended. This type of battery can be expected to last for approximately 12 months on one charging and if not disconnected will remain very stable.

When a newly charged battery is connected to the potentiometer, the current value can be expected to drift for several hours and frequent checks on standardisation will be necessary.

NOTE: If the circuits to be measured are grounded or have a leakage resistance to ground it is important that the battery be adequately insulated. It is good practice to stand the battery on blocks or other clean high insulation resistance material..

6. TEMPERATURE CONTROL

A mercury-in-glass thermostat set to operate at 28°C detects temperature changes inside the inner box and operates the transistor switch circuit which is located in the external control box. (Fig. 5).

In the "ON" condition the heater winding is supplied with approximately 1.5 amp. d.c. In the "OFF" condition the current is reduced to approximately 75mA. On and off conditions of the transistor switch are indicated by the pilot lights on the control box. Cycling time depends on ambient temperature and at an ambient of 22°C to 25°C the period should be about two to three minutes. The switching of the transistor circuit is arranged to take several seconds in each direction so that switching transients are avoided.

7. OPERATION AS A POTENTIOMETER

7.1) Installation

7.1.1) The potentiometer may be installed on a level bench or with a front to back slope not greater than 45°. The location of the potentiometer should be carefully chosen to avoid proximity to heating equipment or electrical equipment with a large heat dissipation. Outside windows from which cold air currents may be expected, or through which sunlight could fall on one side of the potentiometer should also be avoided.

7.1.2) Installation of thermostat and thermometer

The mercury-in-glass control thermostat and the thermometer are packed separately for shipment and are taped to the instrument top panel. To install the thermostat remove the strip panel at the rear of the instrument. This uncovers the terminals. At the left hand end of the terminal strip is a hole into which the control thermostat should be inserted and adjacent to it is a jack for the thermostat plug. A small amount of grease on the thermostat bulb will help to make good thermal contact with the heater block.

The angle thermometer should be inserted into the hole on the top panel so that the engraved scale section lies in the clip tray.

7.1.3) Connect the three pin plug on the cable from the heater control unit to the socket on the back of the potentiometer. Plug the cord on the heater control unit into 110V 60c/s supply. The "on" lamp on the control unit will light and will remain lit until the temperature of the control thermostat inside the potentiometer reaches its switching temperature. This temperature is indicated by the angle thermometer which should read approximately 28°C, but this temperature may not be reached until several hours after the control unit has begun to cycle.

7.1.4) Mount the galvanometer amplifier Type 5214 on a stable base, preferably not the working bench, but in a position where the front controls are easily accessible. A small rigid stand on the floor below the bench is recommended.

7.1.5) Mount the secondary galvanometer associated with the amplifier behind the potentiometer and with the scale slightly below eye level. If a second galvanometer is to be used on the REF circuit this should be mounted by the side of the measuring galvanometer.

7.2) Connections

7.2.1) Remove the strip panel at the back of the instrument by lifting vertically and simultaneously on the two small handles to uncover the terminals.

7.2.2) Connect a 6 volt lead-acid battery to the BATT terminals in correct polarity (See Para. 5).

7.2.3) Connect the measuring galvanometer (See Para. 10.1) to terminals marked G_1 and the critical damping resistor for the galvanometer to the terminals marked G_D.

7.2.4) Connect a monitoring and standardising galvanometer (see Para. 10.2) to the terminals marked G_2 and the associated critical damping resistor across the G_D terminals.

NOTE: See Para. 3.7 for method of connection of external leads to the long stem copper terminals. For connections where thermal emfs are important, eg. galvanometer and measuring leads, it is good practice to use plastic insulated solid copper wire. The use of tinned wire or stranded wire should be avoided. Since the terminal bodies are in solid copper care should be taken not to cause distortion of the thread by overtightening. The incoming leads should make a complete circle under the terminal head so that the head does not tilt as the terminal is tightened.

7.2.5) Replace the terminal cover panel.

7.3) Standardisation Against an Internal Standard Cell (See also Para. 7.11)

7.3.1) Turn the standard cell and reference voltage selector switch to SC1 or SC2 as required.

7.3.2) Turn the SC dial to the correct setting for SC1 or SC2 determined as described in Para. 7.11 and set the mechanical zero of the monitoring galvanometer.

7.3.3) Press the low sensitivity key (L) for the REF or monitoring galvanometer.

7.3.4) Commencing with the x10 dial on the current control adjust the potentiometer current for zero deflection on the monitoring galvanometer.

7.3.5) Progressively increase galvanometer sensitivity by pressing the medium and high sensitivity keys and at the same time adjusting

the current control for zero deflection.

7.4) Standardisation Against an External Standard Cell

7.4.1) Turn the standard cell and reference voltage selector switch to SCX.

7.4.2) Remove the binding post cover panel, and connect the external standard cell leads to the SCX terminals.

Connect the other end of the leads to the external standard cell.

7.4.3) Set the SC dial to the known voltage of the external standard cell, taking into account any difference between the standard cell circuit and the measuring dials as determined by the procedure described in Para. 9.10.

7.4.4) Adjust the potentiometer current for zero deflection on the monitoring galvanometer as described above.

NOTE: Correct standardisation can be checked at any time by depressing the REF ≡≡ key. The battery current can be expected to drift during the first few hours after connection to the potentiometer. The battery should be left permanently connected to the potentiometer and disconnected only for re-charging.

7.5) Voltage Measurement 0.21 volt to 2.1 volt

7.5.1) If there is some doubt about the magnitude of the voltage to be measured, make a preliminary check with the portable multimeter.

7.5.2) Connect the circuit to be measured to the emf terminals in

correct polarity. (Fig. 3a).

7.5.3) Turn the range switch to the appropriate voltage range, x1 or x0.1. The check switch should be in the "READ" position.

7.5.4) Adjust the mechanical zero of the measuring galvanometer to zero, press the low sensitivity galvanometer key ~~I~~ #1 in the "TEST" circuit and adjust the four measuring dials for zero deflection on the galvanometer.

7.5.5) Progressively increase galvanometer sensitivity to medium and high by depressing the ~~M and H~~ 2, 3 and 4 keys and rebalance on the four measuring dials.

7.5.6) When balance has been obtained check that a zero deflection is still obtained on the monitoring galvanometer and if this is not the case re-adjust the potentiometer current on the current control dials for correct standardisation.

7.5.7) Reverse the measuring galvanometer by pressing the ~~R~~ R key and re-adjust the measuring dials, until the deflection (not necessarily zero) does not change on reversal. This eliminates from the reading the effect of thermal emfs in the galvanometer and galvanometer leads. The reading of the four measuring dials then indicates the measured voltage.

7.6) Voltage Measurement Below 0.21 volts

7.6.1) The procedure detailed above should be followed with the exception that the range switch should be in the x0.1 position. The four measuring dials will then read one-tenth of the indicated voltage

to a maximum of 0.210101 0 in steps of 0.1 microvolt.

7.7) Voltage Measurement Above 2.1 volts.

7.7.1) Connect the voltage E to be measured to the input terminals of a volt ratio box and the output terminals of the volt ratio box to the emf terminals on the potentiometer in the correct polarity. (Fig. 3b).

7.7.2) The input terminals used on the volt ratio box should be such as to give an output voltage e which will utilize all four measuring dials on the potentiometer on either the x1 or x0.1 range.

7.7.3) Measure the volt ratio box output voltage e as described above. The total voltage E is given by:

$$E = dFR$$

where d is the reading of the four measuring dials,
F is the potentiometer range factor 0.1 or 1,
R is the ratio of the volt box for the particular terminals used.

7.8) Current Measurement

7.8.1) Connect the current circuit to be measured to the current terminals of a standard resistor having a resistance value such that the voltage appearing at the potential terminals gives maximum discrimination on the four measuring dials of the potentiometer on either the x1 or x0.1 range.

7.8.2) Connect the potential terminals of the four terminal standard resistor to the emf terminals on the potentiometer in correct polarity. (Fig. 3c).

7.8.3) With the potentiometer correctly standardised, obtain a balance on the measuring galvanometer as described above,

7.8.4) The magnitude of the current in the standard resistor is given by $I = \frac{EF}{R}$ where E is the potentiometer reading, R is the resistance of the four terminal standard and F is the potentiometer range factor 0.1 or 1.

7.9 Resistance Comparison

NOTE: IT IS NOT NECESSARY TO STANDARDISE THE POTENTIOMETER AGAINST A STANDARD CELL FOR RESISTANCE COMPARISON.

7.9.1) As can be seen from the circuit diagram four reference voltages are available at the SCX terminals as selected by the standard cell and reference voltage selector switch. These have nominal values of 0.1, 0.2, 0.5 and 1 volt with reference to the measuring dials of the potentiometer and their ratio to the measuring dials can be adjusted by ±50 parts per million as indicated by the red engraving on the Standard Cell Fine Control.

7.9.2) Connect the two 4 terminal resistors to be compared in series through their current terminals and in series with a suitable current control resistor and battery supply. (Fig. 3d).

7.9.3) Connect the potential terminals of the standard resistor to the SCX terminals through one double pole section of a Type 9145 selector switch and connect the potential terminals of the resistor to be measured to the emf terminals through another double pole section of the 9145 selector switch.

7.9.4) Connect the monitoring galvanometer and measuring galvanometer to G_2 and G_1 as before.

It is possible to make resistance comparisons without the use of a 9145 selector switch if the two resistors are connected to the galvanometer terminals and the galvanometers to the SCX and EMF terminals. This enables both poles of the potential leads to be isolated but under these conditions the R galvanometer keys must not be used, and it therefore is not possible to take galvanometer reversals.

7.9.5) Turn the standard cell and reference voltage selector switch to a reference voltage which will give a ratio to the main dial settings appropriate to the ratio between the standard resistor and the measured resistor. Confirm that the CHECK switch is in the "READ" position.

7.9.6) Press the selector switch button for the standard resistor and using the REF galvanometer keys obtain a balance between the voltage drop across the standard resistor and the reference voltage by adjustment of the current through the two resistors (and/or adjustment of the current through the potentiometer) until a balance is obtained.

7.9.7) Press the selector switch button for the measured resistor and obtain a similar balance between the potentiometer measuring dials on either x1 or x0.1 range using the measuring galvanometer and test galvanometer keys but without disturbing the current in either circuit. The ratio between the setting of the measuring dials and the reference voltage is then the same as the ratio between the unknown resistance and the standard resistance.

NOTE: If the standard resistor has known error which is less than ±50 parts per million a correction of the same magnitude can be made to the reference voltage by use of the standard cell fine control using the red engraving figures. When this has been done, the error of the standard resistor may be neglected in computing the value of the measured resistor.

7.10) Comparison of External Standard Cells

7.10.1) Connect the known standard cell and up to ~~three~~ four cells to be measured to the ~~four~~ five outgoing circuits of the Type 9145 press button

selector switch taking particular care to connect the same polarity in each case and making connections to the cells last in order to avoid accidental short circuits. Connect the potentiometer side of the four selector circuits to the EMF terminals on the potentiometer.

7.10.2) Set the measuring dials of the potentiometer to the voltage of the known cell. Press the selector switch button connecting the known cell to the potentiometer.

7.10.3) Press the ~~low~~ #1 sensitivity "Test" galvanometer key and adjust the potentiometer current control rheostat for balance on the measuring galvanometer. Increase sensitivity with the ~~medium and high~~ 2, 3 and 4 sensitivity keys and make an exact balance with reversal. Release the "Test" galvanometer keys.

7.10.4) Press the Type 9145 selector switch button connecting the first cell to be measured to the potentiometer in place of the known cell. Successively press the ~~low, medium and high~~ 1, 2, 3 and 4 galvanometer sensitivity keys and adjust the potentiometer measuring dials for a new balance. It should not be necessary to move Dial I and only rarely necessary to move Dial II. Most adjustments should be possible on Dials III and IV only. When balance has been obtained the measuring dials indicate the voltage of the measured cell in terms of the known cell.

7.10.5) Repeat the same procedure for the other cells checking from time to time that a balance can still be obtained against the known cell

and making adjustments to the potentiometer current as necessary.

7.10.6) ALTERNATIVELY, the known cell can be connected to the SCX terminals and balanced against the standard cell dial on the monitoring galvanometer.

7.10.6.1) This method is particularly useful if a large number of cells are to be checked and enables a continuous monitor to be kept on the potentiometer current without resetting the measuring dials. The correction to be applied for the error in equality between the standard cell dial and the measuring dials can be determined as described in Para. 9.10.

7.10.6.2) When using the alternative method connect the known cell to the SCX terminals, turn the standard cell and reference voltage selector switch to SCX and set the standard cell voltage dial SC to the known cell voltage plus or minus the correction mentioned above.

7.10.6.3) Using the ~~low, medium and high~~ "REF" sensitivity keys, adjust the potentiometer current for balance. Leave the ~~high~~ #4 ~~positive~~ key depressed so that a continuous observation can be made on potentiometer current drift and so that corrections can be made on the current rheostat as necessary.

7.10.6.4) Connect the cells to be measured to the potentiometer EMF terminals, either directly or through the Type 9145 press button selector switch and obtain a balance on the potentiometer

measuring dials as before. The reading of the measuring dials gives the measured cell voltage in terms of the known cell voltage to parts per million.

7.11) Comparison of the Internal Saturated Standard Cells with an External Cell

7.11.1) Connect the known external cell to the EMF terminals, set the measuring dials to the known cell voltage on the x1 range and adjust the potentiometer current for balance on the measuring galvanometer.

7.11.2) Link the SCX terminals and turn the standard cell and reference voltage selector switch to SC1. Press the low sensitivity "REF" galvanometer key and obtain a preliminary balance on the REF or monitoring galvanometer by adjustment of the standard cell voltage dial SC. Progressively increase sensitivity and obtain a fine balance.

7.11.3) The reading of the standard cell dial SC then indicates the setting to be used with SC1 to give correct standardisation of the potentiometer in terms of the known external cell, automatically taking into account the error between the standard cell dial and the measuring dials. Repeat the comparison for SC2.

8. OPERATION AS A VARIABLE FOUR TERMINAL RESISTOR

8.1) The resistance of the potentiometer circuit with the range switch in each of its three positions is given in Para. 4.5.

8.2) When used as a variable four terminal resistor the current is applied

at terminals C_I and C_0 and the potential is taken from the EMF terminals.

8.3) The potentiometer can be used as a four terminal resistor in exactly the same way as a conventional four terminal resistor but with variation of effective resistance up to a maximum of 105.050 50 ohms. The current through the C_I C_0 terminals should not be allowed to exceed 100mA.

9. LINEARITY CHECKING PROCEDURE

9.1) The linearity of the potentiometer and the accuracy of the reference potentials can be checked by use of the built-in checking resistors.

9.2) Equipment Required:

9.2.1) A second potentiometer with similar discrimination as the Type 9144 but not necessarily linearly accurate.

9.2.2) A galvanometer or other detector giving a sensitivity of 100mm/uV in a total circuit resistance of 200 ohms.

9.3) To check Dial I coils in Groups of Five

9.3.1) Connect the external potentiometer to the EMF terminals and open circuit the CK terminals. Turn the range switch to x1 and the check switch to "DIR 1-3". Connect the galvanometer to the G_I terminals and set Dials II, III and IV to zero. With this direct connection the external potentiometer is in opposition to the 9144 potentiometer measuring dials.

9.3.2) Turn Dial I to position 5. Set the external potentiometer also to 0.5 volt. Press the high sensitivity key on the external potentiometer and the low sensitivity key on the 9144. Adjust the current through either or both potentiometers with progressively increasing sensitivity to obtain zero deflection on the galvanometer. The external potentiometer is then exactly balancing the potential across five steps of Dial I. Release the galvanometer key on the 9144, turn Dial I to zero and the CK switch to CK1. The first five steps of Dial I have then been removed from the circuit and the CK1 tapping in the reference network plus the total of Dial II have been included in the circuit. Press the ~~high positive~~ #4 TEST sensitivity key on the 9144 potentiometer and observe the galvanometer deflection. This deflection is due to the difference between the first five coils of Dial I and the total of the CK1 reference resistor plus Dial II. This difference can be reduced to zero before checking the whole dial by an adjustment on the standard cell fine dial.

9.3.3) Return Dial I to position 5 and the check switch to DIR 1-3. Re-adjust potentiometer current for exact balance and turn Dial IV to position 1. The galvanometer deflection so obtained is due to an error in balance of 1 microvolt and the galvanometer sensitivity should be adjusted to make this deflection approximately 100mm. Restore Dial IV to zero and repeat the substitution of the CK1 resistors for the first five steps of Dial I. If the adjustment of the standard cell fine dial has been made the galvanometer deflection should be

less than 10mm. Record this error.

9.3.4)Release the galvanometer sensitivity key, turn the external potentiometer dials to 1.0 volt and Dial I to position 10 with the check switch at DIR 1-3. Rebalance the current and check the galvanometer sensitivity for 1 microvolt as before. Release the galvanometer key, return Dial I to position 5 and turn the check switch to CK1. Press the high sensitivity galvanometer key and observe the deflection. This deflection is due to the difference between the second group of five coils of Dial I and the check resistor.

9.3.5) Repeat the same procedure for each group of five coils of Dial I up to 20, tabulate the results and deduce the overall linearity of the dial.

9.3.6)If the external potentiometer does not have a sufficiently high range to reach the full 2 volts of the 9144 potentiometer, increase the current through the external potentiometer or reduce the current through the 9144 by the addition of resistance in the battery lead. The actual potential values used is of no importance provided that an exact and stable balance between the 9144 and the external potentiometer can be achieved.

9.4)To check Dial II coils in groups of 10

9.4.1)Connect the external potentiometer to the CK terminals and leave the EMF terminals open.

9.4.2)Turn Dial II to position 10 and the other measuring dials to

zero. Set the external potentiometer to nominally 0.01 V. Turn the check switch to DIR 2. Obtain a balance between the 10 steps of Dial II and the external potentiometer by adjustment of potentiometer current as before. Adjust galvanometer sensitivity for a 1 microvolt step of Dial IV.

9.4.3) Restore Dial II to zero and turn the check switch to CK2. Press the galvanometer key and observe the deflection due to the difference between the CK2 resistor and the first 10 coils of Dial II.

9.4.4) Release the galvanometer keys, turn the check switch back to DIR 2 and Dial II to position 20. Press the galvanometer key and adjust current as necessary. Release the galvanometer key, restore Dial II to position 10 and turn the check switch to CK2. Press the galvanometer key and observe the deflection due to the difference between the second group of 10 coils of Dial II and the check resistor.

9.4.5) Repeat the procedure for each group of 10 coils of Dial II up to 100, tabulate the difference between each group and the check resistor and deduce the linearity of the dial.

9.5) To check Dial III coils in groups of 10

9.5.1) Connect the external potentiometer to the EMF terminals

and leave the CK terminals open.

9.5.2) The procedure used to establish the linearity of Dial III is exactly as described for Dial II. Using check switch positions DIR 1-3 and CK 3 each group of 10 coils is compared to a check resistor.

9.6) To check equality of steps of Dial IV

9.6.1) The linearity of Dial IV in which an error per step of 1% is equivalent to only 0.01 microvolt on the x1 range can be checked to a sufficient order of accuracy by galvanometer deflection and an external potentiometer is not required.

9.6.2) Connect a link between the EMF terminals and a link between the CK terminals. Turn Dial I, II and III to zero and Dial IV to position 10. Turn down the gain on the galvanometer so that a deflection of 100 mm is obtained for the 10 steps of Dial IV. Reduce the setting of Dial IV step by step observing that the galvanometer deflection increments are approximately equal.

9.7) Complete Linearity Check on Dial I

9.7.1) The test conducted as described in Para. 9.3 provides a quick check on the linearity of Dial I in groups of 4 coils. To obtain

a full picture of the linearity of the dial it should be checked step by step against the total of Dial II.

9.7.2) Connect an external potentiometer to the EMF terminals and link the CK terminals. Turn the check switch to the READ position, Dial I to position 1 and Dials II, III, and IV to zero. Adjust the external potentiometer to approximately 0.1 volt, and with increasing sensitivity adjust the current in either or both potentiometers for zero deflection on the galvanometer.

9.7.3) Release the galvanometer key, restore Dial I to zero and turn Dial II to 100. Press the ~~high~~ #4 TEST sensitivity key and record the galvanometer deflection due to the difference between the first step of Dial I and the total of Dial II.

9.7.4) Balance two steps of Dial I against the external potentiometer with Dial II at zero. Reduce the setting of Dial I to 1 and increase Dial II to 100. Observe the deflection due to the difference between the second step of Dial I and the total of Dial II.

9.7.5) Repeat the same procedure for each step of Dial I up to 20. Check the sensitivity of the galvanometer before each comparison. It is easily possible to obtain a comparison between steps of ±0.1 microvolt equivalent to ±1ppm throughout the dial, provided that the current in both potentiometers is stable. In the upper half of the dial however, it will be found that great care is necessary to avoid errors due to differing rates of current drift in the two potentiometers.

9.8) To check equality of the total of each of Dials II, III and IV with one step of the next higher dial

9.8.1) Using the same system as described for obtaining dial linearity, make a comparison between the total of Dial II and the first step of Dial I; the total of Dial III against the first step of Dial II, and the total of Dial IV against the first step of Dial III.

9.9) Comparison of the reference potentials with the measuring dials

9.9.1) Short circuit the EMF terminals on the 9144 potentiometer with a short length of clean copper wire. Link the CK terminals and after turning the standard cell and reference potential switch to one of the reference potentials, link the SCX terminals. Connect the galvanometer to the galvanometer terminals on the external potentiometer. Connect both G_1 and G_2 terminals to the EMF terminals on the external potentiometer (Fig. 4).

9.9.2) Set Dial I to 0.1 volt and the external potentiometer dials to the same voltage. Set all other measuring dials to zero. Turn the standard cell fine control to the center or zero position as shown by the red engraving and the reference emf selector switch SC to 0.1 volt. Press the galvanometer key on the external potentiometer and adjust the current in either or both potentiometers to obtain zero deflection using the ~~low, medium and high~~ 1, 2, 3 and 4 sensitivity TEST keys. Adjust galvanometer sensitivity to give a deflection of 100mm for a one microvolt step of Dial IV.

9.9.3) Release the TEST galvanometer positive key and press the

REF galvanometer positive key. The galvanometer deflection indicates the difference between the first step of Dial I and the 0.1 volt reference tap. Reduce this deflection to zero by adjustment of the standard cell fine control and note the reading indicating the difference in parts per million.

9.9.4) Repeat the same procedure for 0.2, 0.5, and 1 volt positions of the reference voltage selector switch SC and note the difference between these voltage tappings and the corresponding settings of Dial I in parts per million.

9.10) Comparison of standard cell dial with measuring dials on x1 range

9.10.1) Use the same circuit connections as described in Para. 9.9.1 and as shown in Fig. 4. Set the measuring dials to 1.017 500 volts on the x1 range and the standard cell dials SC to the same potential. Turn the standard cell selector switch to SCX.

9.10.2) Obtain a balance between the measuring dials and the external potentiometer using the TEST galvanometer keys. Release the TEST keys and press the high ~~positive~~ #4 galvanometer key in the REF circuit. Adjust the SC fine control for balance. Note the divergence of the SC fine control in ppm as the correction for the standard cell dial.

9.11) To check potentiometer zero error

9.11.1) Link the EMF terminals and the CK terminals. Turn the four measuring dials to zero and the check switch to READ. Press

the ~~high~~ #4 sensitivity TEST key and adjust galvanometer sensitivity so that 1uV gives a devlection of 100mm. With all four dials at zero disconnect the battery and note the change in deflection. This change is due to the zero error of the potentiometer.

10. ACCESSORIES

10.1) Measuring Galvanometer

The measuring galvanometer should have a sensitivity such that the smallest voltage increment (0.1 microvolt on the x0.1 range) can be easily detected when the total circuit resistance consisting of the potentiometer and the circuits to be measured, is connected in series. It is also a matter of considerable convenience to have a control on the detector sensitivity. The Tinsley Type 5214 Photocell Galvanometer Amplifier meets these requirements. The secondary galvanometer Type SR21 used with the amplifier has a 130-0-130mm scale.

10.2) Monitoring and Standardising Galvanometer

The galvanometer used on the REF circuit should have a sensitivity such that the smallest divisions on the standard cell fine dial give detectable deflections in a circuit resistance which consists principally of the internal resistance of the standard cell. For saturated cells of the type included in the potentiometer, this is between 700 and 1000 ohms. The Tinsley portable galvanometer Type 4500/SR4 with 50 ohm system gives the best compromise between sensitivity and damping.

10.3) The battery used to supply the potentiometer current should be of the charge retaining type and should be removed from load only for re-charging. The Willard Type DD-3-3 battery is recommended.

10.4) Volt ratio boxes and current measuring shunts to extend the voltage measuring range to 1500V and for current measurement up to 2250 amperes are available in the Guildline range.

10.5) External Selector Switch (Low Thermal Selector Switch Type 9145)

The Type 9144 potentiometer has one pair of EMF terminals and it is intended that when it is required to make measurements on more than one external circuit, a type 9145 Selector Switch should be used. The 9145 Selector Switch gives facilities for the connection of ~~four~~ five external circuits, each of which can be separately connected to the EMF terminals of the potentiometer by means of press buttons. The construction of the switch is similar to the construction of the galvanometer sensitivity keys with double pole copper contacts. Close thermal bonding is used and generation of thermal emfs in the switch is less than 0.01 microvolt.

11. MAINTENANCE

11.1) The only maintenance which should be regularly necessary is an annual cleaning of the switch contacts. These are situated immediately below the top panel of the instrument. It is not necessary to remove the instrument from the outer box to obtain access to the switches.

11.1.1) Remove all knobs except the galvanometer press keys. A small countersunk screw holds the standard cell fine control knob. Removal of this knob uncovers the three screws which hold the standard

cell coarse control disc. Remove this disc. All other knobs may be pulled vertically off the switch shafts. Knobs and shafts are correspondingly numbered. Take out the five 18-32 countersunk screws holding the top panel to the sub-panel and the four 8-32 screws which hold the top panel to the box and lift off the panel.

11.1.2) 100 Position Switches, Dials II and III

Remove 3 screws securing the switch shaft to the click disc. Remove the shaft to expose a further 3 screws securing the click disc to the lower bearing. Lift off the click disc. Clean the switch contacts, and in the case of the third dial the continuously varying compensating rheostat winding, by wiping lightly with a clean chamois leather. Re-lubricate these surfaces with a few drops of good quality switch lubricant spread uniformly over the contact surfaces. Clean the brushes attached to the click disc with a stiff bristle brush dipped in carbon tetrachloride or other cleaning solvent. Re-lubricate the brushes with switch contact oil. Re-assemble the switch using the reverse of the procedure detailed above.

NOTE: THE SWITCH SHAFT AND CLICK DISC ARE MARKED TO GIVE CORRECT RELATIVE POSITIONS. MAKE SURE THAT THESE MARKS ARE COINCIDENT SO THAT THE ENGRAVING ON THE SWITCH DISC WILL AGREE WITH THE SWITCH POSITION.

11.1.3) Standard Cell Dial and Standard Cell Selector Switches

These two switches have aluminum covers which may be removed by

taking out the two fixing screws. It is not recommended that the standard cell coarse switch be further dismantled. Two or three drops of lubricating oil may be placed on the switch studs to renew the lubrication.

11.1.4) Standard Cell Selector Switch, Dial I, Dial IV, Check Switch, Range Switch and the three upper decades of the current control.

Remove the three screws securing the switch shaft to the click disc. Note the relative position of the shaft and the click disc and if necessary, mark these to facilitate re-assembly in the correct relative position. Remove the small locking screw in the centre of the large fixing screw. Remove the fixing screw. Lift off the click disc and brush carrier assembly. With a pair of tweezers, rotate each brush through 90° and lift it clear of the switch studs. Wipe the switch studs with clean chamois leather and re-lubricate as described above. Clean and re-lubricate the brushes.

Note: Replacement of the brushes may be facilitated by removal of the switch end stop so that the brushes can be introduced through the gap between the first and last switch studs.

Repeat the same procedure for all the other switches listed.

11.1.5) Galvanometer Sensitivity Keys

~~Remove the three screws holding the cover plate on the back of the switch assemblies.~~ With a short length of clean wire, place a drop of switch lubricating oil on each switch contact. Do not overlubricate. It is

not recommended that the galvanometer key assemblies be further dismantled.

11.1.6) Replace the potentiometer top panel and knobs.

11.2) WARNING. The resistors in this instrument have been adjusted to an extremely high degree of accuracy and their stability depends to a large extent on the fact that they are not touched or disturbed in any way. So that minor adjustments can be made to linearity a series of small trimming resistors have been included in critical parts of the circuit. These are located on top of the sub-panel and are arranged to have an adjusting range of a few parts per million. If the instrument is returned to the factory after one or two years for overhaul and calibration check, these trimmers can be used to make minor adjustments without touching resistance elements themselves and thereby causing instability which could be expected to give rise to further long term drift.

THE USER IS STRONGLY ADVISED AGAINST MAKING ANY ADJUSTMENTS ON THE TRIMMING RESISTORS AND AGAINST ATTEMPTING TO REMOVE THE INSTRUMENT FROM ITS CASE.

11.3) Thermostat. The internal temperature is controlled by a mercury-in-glass thermostat. This is arranged to work at a very low power level and should not require attention. In the event of failure however, it may be removed and replaced through the disc cover on the back of the box as

explained in Para. 7.1.2.

THE INNER CASE IS SEALED AND BREAKING OF THE SEAL AUTOMATICALLY CANCELS THE GUARANTEE. SPECIAL LIFTING HANDLES ARE REQUIRED TO REMOVE THE INSTRUMENT FROM THE CASE AND THESE ARE AVAILABLE ONLY FOR FACTORY USE.

Guild LINE INSTRUMENTS LTD.
FORMERLY TINSLEY INSTRUMENTS (CANADA) LTD.
MANUFACTURERS OF
PRECISION ELECTRICAL MEASURING INSTRUMENTS

BOX 99
SMITHS FALLS
ONTARIO • CANADA

TELEPHONE: 283-3000
AREA CODE: 613

YOUR REF.

OUR REF.

CERTIFICATE OF CALIBRATION

Instrument Type . 9144 . . . . Serial No. . 23726 . . .

This instrument has been calibrated against standards maintained in our plant standards laboratory. At regular intervals these standards are compared with national electrical standards by National Research Council in Ottawa or the National Bureau of Standards in Washington, D.C. A calibration history covering many years has been accumulated.

Four terminal resistors with decade values between 0.0001 ohm and 100,000 ohms serve as resistance standards. For intercomparison purposes the resistors are immersed in constant temperature oil and compared on six figure potentiometers with known linearity within ±0.0002%.

Voltage standards are maintained by means of groups of saturated cadmium cells in enclosures controlled to ±0.01C°. Their voltages are compared with the national voltage standard at regular intervals with a precision of ±0.0001%.

Standards of inductance are maintained in the form of fixed inductors wound on white Sicilian marble. Their value is known to within ±0.01%.

Date .AUGUST..1963. Certified by .....

GUILDLINE INSTRUMENTS LTD.

CERTIFICATE OF COMPLIANCE

This is to certify that Potentiometer Type 9144, Serial No. ..23726..... conforms to our standard catalog specification.

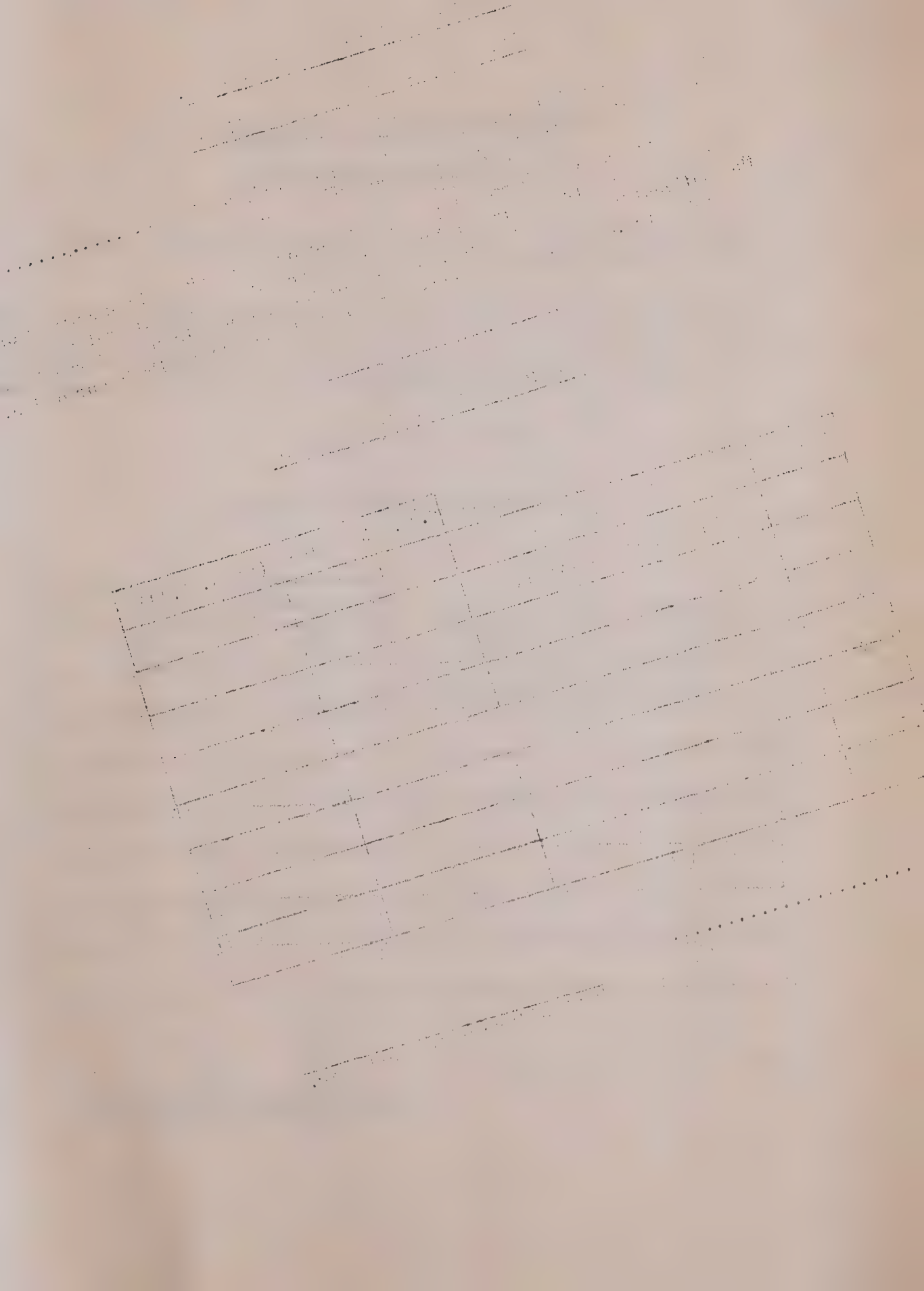
The instrument was thoroughly tested in accordance with this specification before shipment from our plant using reference standards calibrated by the National Research Council in Ottawa or the National Bureau of Standards in Washington. Complete records of the final tests are on file in our office.

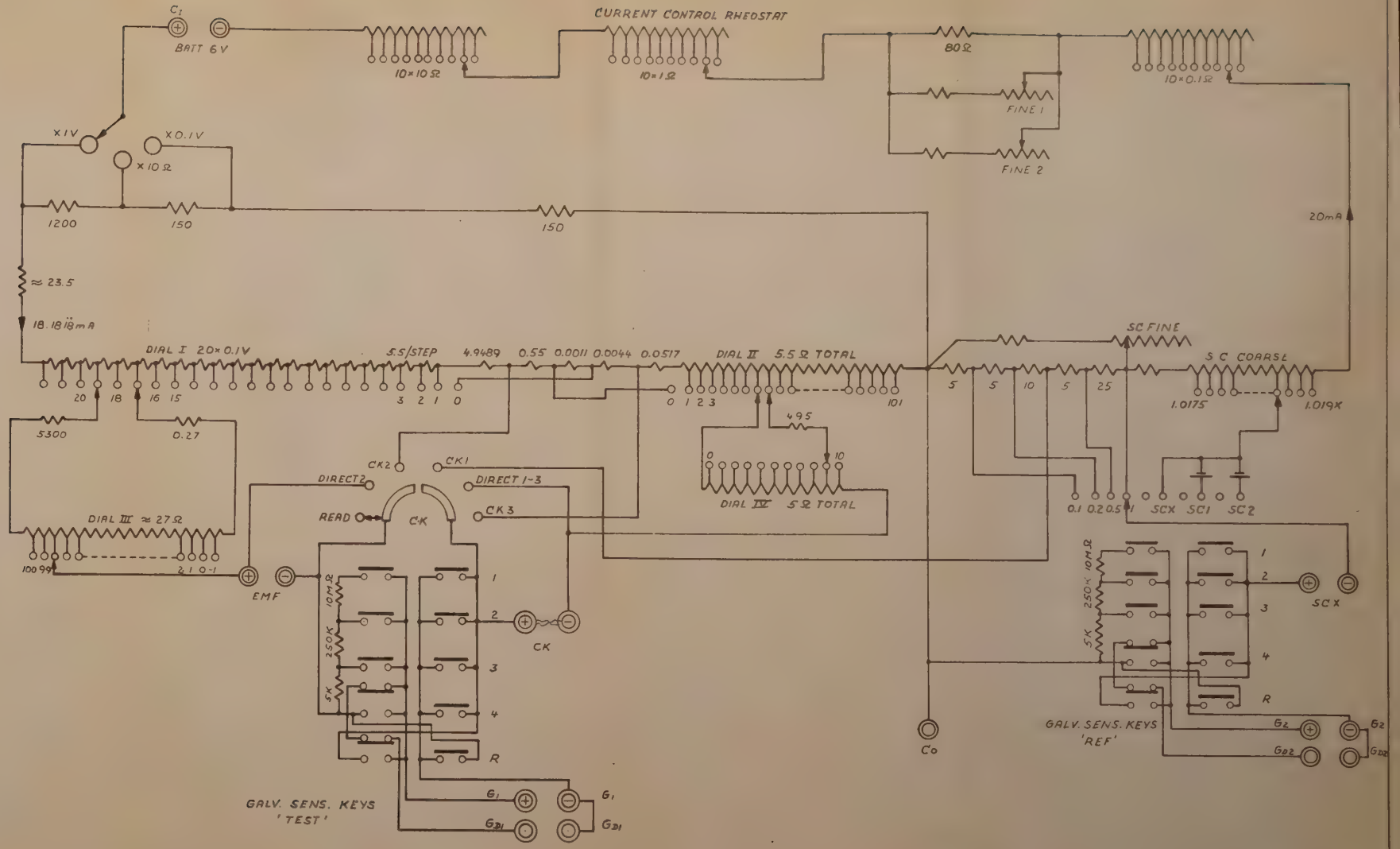
INTERNAL STANDARD CELLS

		S. C. dial setting (Para. 7.11)	
DATE	REFERENCE	SC1	SC2
	PLANT STANDARDS	1.01825	1.01825

Date ...AUGUST..1963.....

for Guildline Instruments Ltd.





			GUILDLINE INSTRUMENTS LTD. SMITHS-FALLS/ONT.
		DATE:	11-15-62
		DRAWN:	Plow
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JUNE 63	3	SCALE:	
NOV. 62	2		POTENTIOMETER TYPE 9144 FIG. 1 SCHEMATIC CIRCUIT

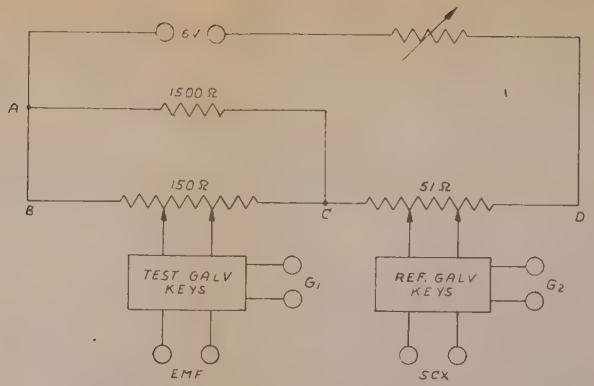

FIG. 2a
X1 VOLTS RANGE

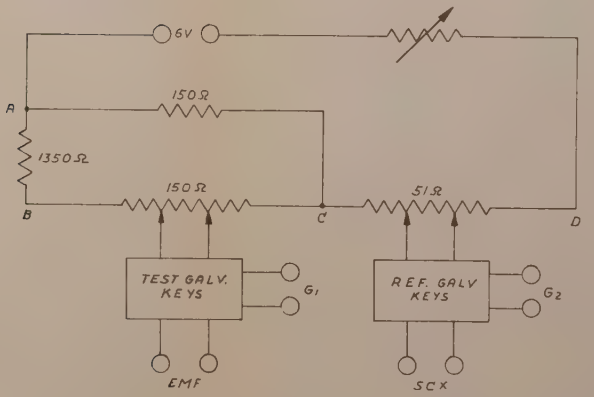

FIG. 2b
X0.1 VOLTS RANGE

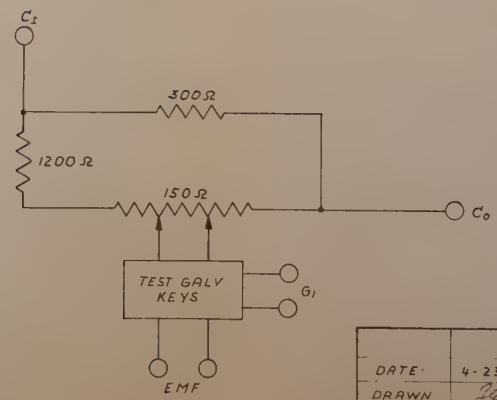

FIG. 2c
X10 OHMS RANGE

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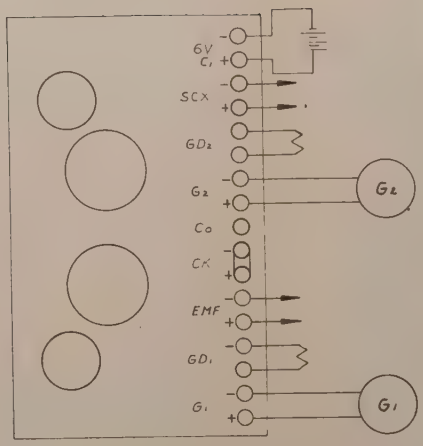
SCALE	/	



POTENTIOMETER TYPE 9144

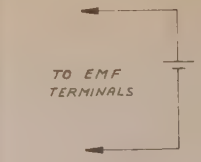


FIG. 3a
VOLTAGE
MEASUREMENT
BELOW 2.1 VOLTS

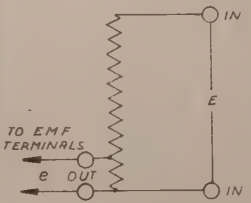


FIG. 3b
VOLTAGE
MEASUREMENT
ABOVE 2.1 VOLTS

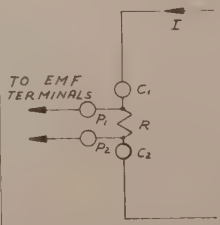


FIG. 3c
CURRENT
MEASUREMENT

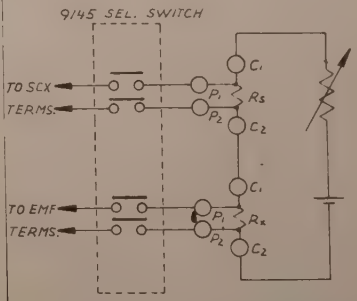


FIG. 3d
RESISTANCE
COMPARISON

		GUILDLINE INSTRUMENTS LTD SMITHS-FALLS/ONT.
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DRAWN	Jean	9144 POTENTIOMETER
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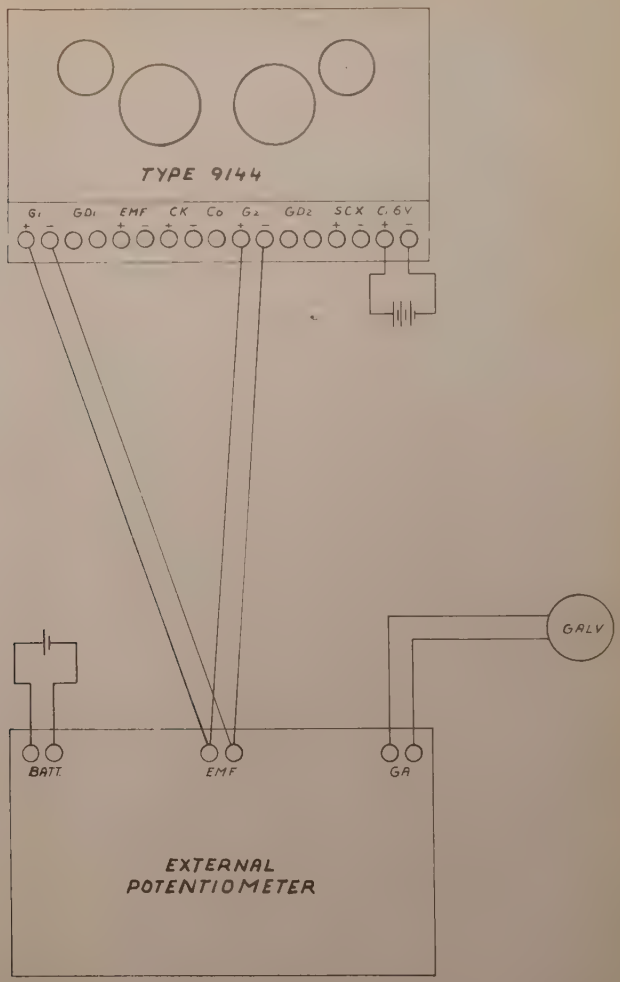
SCALE		
DATE	ISSUE	



			GUILDLINE INSTRUMENTS-LTD SMITHS-FALLS/ONT.
		DATE	2-27-63
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		CHECKED	
		SCALE	
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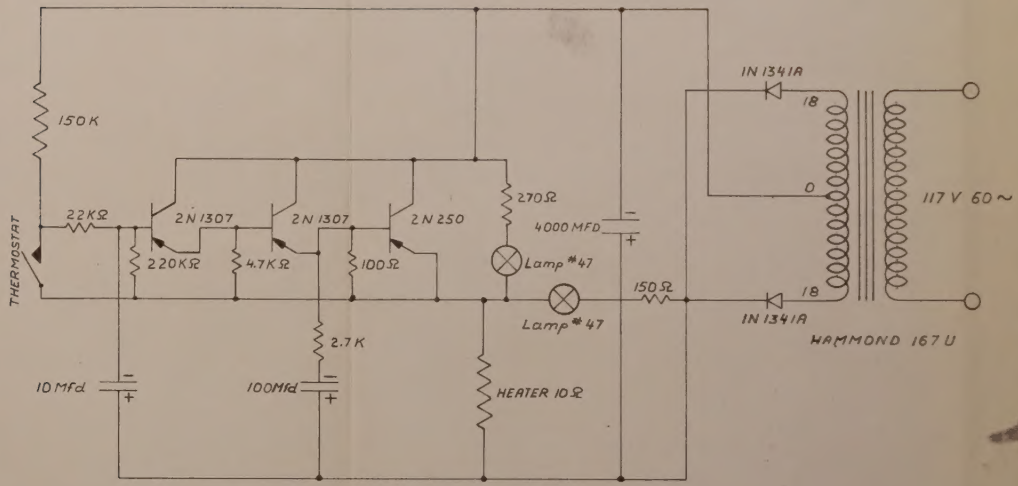
POTENTIOMETER
TYPE 9144 FIG 4
COMPARISON OF REFERENCE
CIRCUIT AND MEASURING DIALS



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		DATE:	2-26-63
		DRAWN:	Clare
		CHECKED:	
2-26-63	5	SCALE:	TRANSISTOR SWITCH 9144 FIG. 5
DATE:	ISSUE:		

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TANGERINE/TANGERINE/ANARANJADO ROJI
MADE IN USA